

# The Future of California's Inland Fishes

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I'm going to start with my conclusion, which is that in the next 50 years we will most likely see a severe decline in our native fishes, including salmon, if present trends continue. Let me remind you how remarkable our native fish fauna is. Half our native fishes are found only in California, and another quarter or so are shared with just one other state. Even the widespread species such as salmon and steelhead have distinct California populations. But unfortunately we're not doing a very good job of conserving them. Only about 40% of the species are fairly secure right now.

Why should we care about native fishes? First, under the Endangered Species Act and other laws, the citizens of this country say we have to care. This makes fish populations one of the key response variables that drive conflicts over water. Equally important, native fish are good indicators of the health of our aquatic ecosystems in general.

Looking at the 10-year period since the Bay-Delta Accord was signed in 1994, there's a lot of evidence suggesting things have gotten better for fish due to CALFED-sponsored research and actions. Splittail has been delisted, salmon runs have been large, no species have gone extinct, and most have at least maintained their status quo. Of course we also need to recall that the early 1990s marked the end of the drought. Will the next 50 years be as benign?

I'm pessimistic about the future of native fishes because of the probable combined impacts of climate

change, rising sea level, earthquakes, and human population growth. Climate change models predict a 2-4°C rise in mean air temperature in California over the next 50 years, leading to major reductions in the Sierra snowpack, earlier snowmelt, and more precipitation as rain. We are likely to have more severe winter floods and much drier springs and summers. Longer and more severe droughts are also likely, even without climate change. As Jeff Mount will discuss, much of the area of the Delta is below sea level and in the near future we are very likely to see increased flooding of those areas due to sea level rise, earthquakes, and other factors. On top of all this there is the expectation that in the next 50 years the state's population will more than double.

Likely consequences of the above changes include an increased human demand for water, a demand for more water storage, a demand for more and bigger levees, and a higher percentage of the state's free-flowing water flowing in regulated streams. As for the impact on California's inland fishes, I think we can expect more extinct and endan-

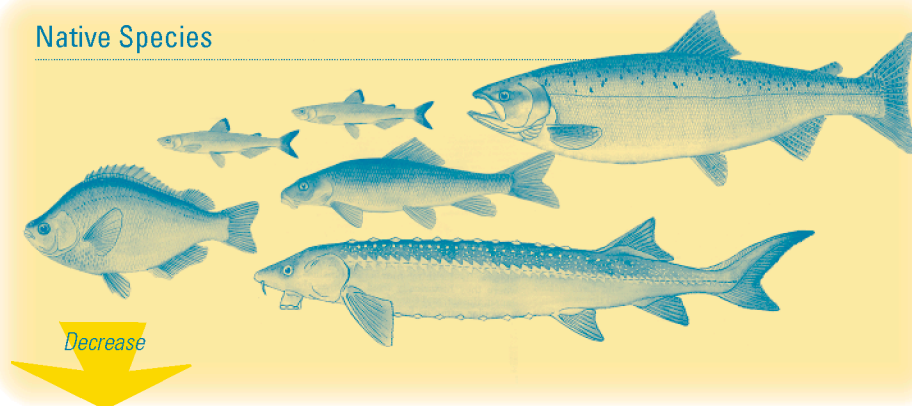
gered fishes; reduced habitat for the nonendangered forms; a decline in fisheries, especially salmon fisheries; and an expansion of the populations of non-native fishes.

California is remarkable because we have the southernmost populations of 12 species of anadromous fish. We can predict that the ranges of these anadromous species will be reduced, abundances will decline, dependence on regulated rivers will increase, and persistence even at present levels will require intense conservation efforts. Spring-run chinook salmon are a major focus of restoration efforts because they were probably once the most abundant salmon in California and they are now down to a few thousand fish. The timing of their adult migration coincides with the period when flow is likely to be significantly reduced as a result of climate change, so they will have less water to migrate through. They are also likely to be affected by reduced flows in the summer, when their juveniles are rearing in the rivers.

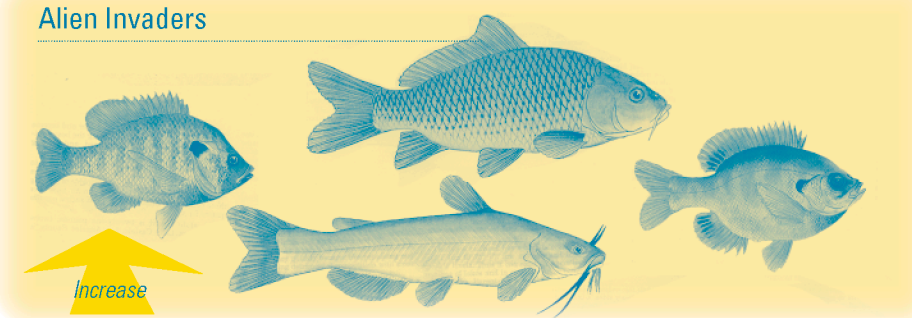
I'm a little more sanguine about the Sacramento splittail because increased frequency of flooding is quite likely to provide more opportunities for spawning success, and the creation of brackish-water habitat in the Delta might also be good as rearing habitat. More brackish habitat might also improve condi-



## Native Species



## Alien Invaders



tions for Delta and longfin smelt but more likely they will continue to be in trouble. As for other native minnows and suckers, I think that in general as habitat declines and more streams dry up in the summer we will see declines in their populations. The ruffle sculpin, a coldwater specialist, will also decline. The prickly sculpin, on the other hand, quite likely will increase because it has pelagic larvae and it already does quite well in reservoirs around the state. Alien invaders such as largemouth bass, carp, and catfish are certainly going to be expanding. They're going to find a lot more habitat with the increasing amount of water in reservoirs and warmer water in lowland habitats.

If we want to save the native fishes, first we need to face reality. We need to recognize that their problems are going to get worse as the result of massive environmental change. This means we need to start planning for large-scale changes in water management, because above all we want to avoid emergency solutions to water-supply problems. Several big water

projects are currently being seriously considered and no doubt some will be implemented. Clearly, expanded storage is in our future—either building more dams (even though there aren't any great sites left) or expanding existing reservoirs. The National Heritage Institute has proposed the radical idea of conjunctive water use—that is, trying to operate our reservoirs and associated aqueducts in conjunction with groundwater storage as if all were parts of one grand water supply system. Then there is the Peripheral Canal, which no one wants to talk about. I think taking this “isolated facility” off the table has been a bit of a mistake because if the Delta becomes a brackish-water habitat, what are the alternatives for getting Sacramento River water down to the

San Joaquin Valley and Southern California? We also have more flooding in our future. It is likely that a lot of Delta land is going to go out of agricultural production as it floods, and we should be planning for that more seriously.

So, what is the agenda for protecting native fishes? What should we be thinking about? Expanding the use of the public trust doctrine would give us a lot of flexibility in terms of protecting native fishes. Since it seems inevitable that we'll have more floodable land, we need to be managing our floodplains for native biodiversity. Restoring flows to the San Joaquin River would be a big help in restoring the spring-run Chinook salmon and other native fishes. We really need to develop better ways to reduce the import and spread of alien species. And of course there's the need to increase the amount of environmental water. All the big water projects should have environmental water as a large part of their dedicated use. The reason

I worry about emergency responses to Delta levee collapses and extended drought is that such responses are much less likely to include water for the environment if cities and farms are demanding water just to keep going. Finally, we need permanent funding for environmental restoration, management, and monitoring. This especially is where the California Bay-Delta Authority is going to have to play an expanded role in the future.

**“...in the next 50 years we will most likely see a severe decline in our native fishes ...”**

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# Fish Protection

Bob Fujimura (CDFG)  
Session Chair

## Background

The San Francisco Estuary and its watersheds have been transformed into one of the most extensively modified and engineered water management systems in the world. These modifications make possible beneficial uses of water, but the combined effects of man-made structures, diversions, alterations in the timing and magnitude of flows, and other human actions have impacted fish populations.

Many of CALFED's actions are intended to benefit fish species of concern. The breadth of topics presented in this session attests to the many forms fish protection can take. Scientists are working within the constraints of a heavily engineered and regulated system. Much of the scientific information presented seeks to elucidate how fish behavior and populations are directly affected by the structures, pumps, and diversions that are here to stay.

CALFED is particularly interested in the Central Valley Project and State Water Project diversions in the South Delta. These diversions pump large amounts of water and are currently screened to minimize fish entrainment, but the screening technology being used is mostly from the 1950s. Delta planning includes the possibility of new screens or modification of the existing intake fish protection facilities, and operational changes to reduce adverse impacts to sensitive fish – especially delta smelt, salmon, steelhead and splittail. Information from past research and work described in this session can help

managers determine if new screens or modifications of existing screens and operations are warranted. The intake to SWP is of special concern since studies indicate that significant numbers of sensitive fish are lost to predators (mainly sub-adult striped bass) in Clifton Court Forebay – a regulating reservoir at the intake.

Several talks focused on the anadromous green sturgeon (*Acipenser medirostris*), which has three known breeding populations along the west coast of North America – the Klamath River, the Rogue River and the Sacramento River. The abundance, productivity, and life history diversity of the Southern population is unknown. Green sturgeon has



been petitioned for listing under the federal Endangered Species Act, and is considered a Candidate Species by NOAA-Fisheries. On the Sacramento River it is classified as a CALFED At-Risk Species. During the summer, sturgeon of unknown origin aggregate in coastal estuaries. Adults return to their natal rivers to spawn after up to around 20 years of marine residence. The work presented here documents the results of some of the first studies conducted in the San Francisco Estuary on this species.

## MANAGEMENT IMPLICATIONS

- Shoulders-on-VAMP likely reduced SWP entrainment of delta smelt. However, the benefit of SWP curtailment depends on the temporal relationship of spawning and Clifton Court diversions rather than on average export rates (Hymanson).
- At the Suisun Marsh Salinity Control Gates (SMSCG), unmitigated gate operations reduced salmon passage. Maintaining an open SMSCG boat lock appears to increase salmon passage (Vincik).
- A new intake structure for the pumps, larger and located closer to the Central Delta, might make up for some of the deficiencies in the current water project operations (Odenweller).
- Potentially large cumulative entrainment losses at water diversions suggest increased use of fish screens may be warranted (Swanson).
- Fish passage facilities may allow for green sturgeon passage if they include areas of high-flow, followed by low-flow resting areas (Webber).
- Sturgeon migratory behavior may be more variable within breeding populations than salmonids. Sturgeon may migrate out of their 'boundaries,' so impacts to sturgeon in the Estuary may occur outside the perceived region of influence, suggesting greater communication among states and tribes may be necessary to manage this species (Israel).
- It may require 10,000 acre-feet/year from Folsom South Canal to open the Cosumnes River for salmon migration. Because the highest rates of seepage loss are concentrated in local reaches, reducing the uncertainty this estimate will require careful monitoring of controlled releases (Fleckenstein).

## SCIENTIFIC INFORMATION

- Rate and timing of diversion of Delta water into Clifton Court Forebay (CCF) have more relevance for understanding impacts on delta smelt than do daily average export rates from the State Water Project (SWP) or the Central Valley Project (CVP) (Hymanson).
- Water temperatures  $>20^{\circ}\text{C}$  appear to motivate young delta smelt movement, leading to high May-June salvage events. Between 2001 and 2004, high SWP salvage events of young delta smelt consistently occurred during or immediately after a low export period and when water temperature was  $>20^{\circ}\text{C}$  (Hymanson).
- Over the past decades, estimates of losses of juvenile Chinook salmon to predators in CCF have varied from 63% to 99%. Predator control efforts have not reduced predation (Odenweller).

## Geographic Distribution of Green Sturgeon



*Species of interest to CALFED can migrate long distances and be impacted by management actions outside of the CALFED program areas. CALFED's efforts to conserve green sturgeon that originate in the Sacramento River may benefit from including fishery managers from other regions (figure courtesy J. Israel).*

- Experimental configurations of the Suisun Marsh Salinity Control Gates (SMSCG) were used to evaluate the effects of the gates and associated structures on fall-run Chinook salmon passage. Normal operational gate configuration with no passage features reduced salmon passage compared with a fully open gate configuration. Early attempts to use modified flashboards with horizontal slot openings resulted in poor salmon passage. Using the boat lock as a fish passage structure showed some improvements in passage during normal gate operations. Relative to its small cross-sectional area, the SMSCG boat lock passed a significant proportion of test fish. Integrating results from all tests since 1993, at least 1/3 of salmon used the SMSCG boat lock for passage (Vincik).
  - Although the entrainment of fish by a single diversion may be difficult to measure directly, cumulative entrainment losses may be large. Entrainment rates may vary depending on the season, environmental conditions, fish abundance and distribution, and diversion location (Swanson).
  - Louvers are used to screen fish from entrainment in large water intakes at the SWP and CVP. Experimental observations of fish response to louvers reveal two distinct behaviors. Passive avoidance (slight shifts in direction) occurs when fish swim within three body lengths of louvers. Fish respond more strongly when closer to the louvers, with a sudden change in swimming direction (Lemasson).
  - Fish ladders are typically designed for salmonids, but other fish may need to pass the same barriers for upstream spawning migration.
- Little is known about the swimming abilities of adult sturgeon, a bottom-dwelling fish with smaller maximal swimming ability. Sturgeon in experimental flumes were able to pass barriers by swimming in bursts over 2.5 m/s, followed by recovery in slower moving waters (Webber).
- Swimming performance in green sturgeon changes as the fish grow, in ways similar to salmonid swimming development. In lab experiments, aerobic swimming ability decreased with the age of juvenile sturgeon, as tolerance to salinity increased (Allen).
  - There is population differentiation between green sturgeon sampled from different locations within the San Francisco Estuary and farther north on the West Coast. These may represent different breeding populations, but there is some evidence of genetic mixing among locations (Israel).
  - Streambed seepage loss models influence estimates of minimum stream flows for fish passage. The standard paradigm that a uniform connection exists between streams and groundwater no longer holds. A heterogeneous model for the Cosumnes River's surface and groundwater suggests that streambed infiltration is discontinuous and local water table recharge occurs in patchy locations. As half of seepage loss in about 25% of the channel, local water management to improve fish passage may be possible (Fleckenstein).

# Central Valley Salmonids

Randy Brown (CBDA)  
Session Chair

## Background

Much management and restoration effort in the San Francisco Estuary and the Central Valley watershed focuses on salmonids – declines in historically abundant populations of these fish have motivated significant actions to help one of the Valley's aquatic charismatic megafauna. Salmonids of greatest concern are Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). Both are anadromous, which means they rear in inland rivers, streams or estuaries, and emigrate to the sea for one to three years before returning to their natal stream to spawn. Many of the Chinook salmon may be harvested in ocean and inland fisheries.

## Chinook salmon

Chinook salmon have a complex life history, and teasing apart the aspects that impact population size is the focus of much scientific effort. From both a biological and management perspective, the time of adult migration is key because it has led to the formation of locally adapted populations. In California's Central Valley the four primary life history types (sometimes called 'races') are the fall, late-fall, winter and spring runs. Winter and spring-run Chinook salmon are listed under the State and Federal Endangered Species Acts as endangered and threatened respectively. Fall and late fall runs are candidate runs pursuant to the federal ESA.

## Steelhead

Unlike Chinook salmon, the

trout *O. mykiss* may exhibit both anadromous (steelhead) and non-anadromous (resident rainbow trout) life history forms. Each can produce progeny of the alternate type and the two forms can interbreed, causing one speaker to refer to them as "just one big happy family." *O. mykiss* populations have been isolated by migration barriers such as waterfalls and dams, but are also found sympatrically. Steelhead is listed as threatened under the Federal Endangered Species Act.

## Management

Salmonid populations are vulnerable to human impacts in a number of ways. Dams are a primary culprit, directly by physically cutting off access to upper reaches of spawning and rearing habitat. Also, regulation of flow patterns by dams affects water temperature and quality – salmonids need cold, oxygen-rich water. Geomorphology is also critical to salmon spawning – dams cut off the supply of coarse gravel that salmon require to build the redds into which the females deposit their eggs. In addition, land use change can increase the supply of fine sediment that clogs spawning gravel. Finally, reduced peak flows decrease the natural cleansing of sediment and active meandering of rivers that once provided suitable spawning and rearing habitat in a watershed's undisturbed state (see the Big Rivers session on page 33 for more background).

Attempts to minimize or mitigate human impacts have taken a number of forms. Direct restoration of habitat, for example through gravel addition projects, is complemented by increased efforts to understand

population-level processes. Other actions have included dam removal, improving fish screens and fishways, increased instream flows, pulse flows, and the temporary installation of barriers to spatially separate spawning areas. Hatchery supplementation is viewed as an important, but controversial, tool for increasing populations.

## Science

Salmonids research was the largest single category of research presented at this conference, reflecting the importance of this topic. This session highlights a substantial and broad research program currently underway in the

Central Valley and the San Francisco Estuary. Analysis of growth rings in otoliths (fish ear bones), genetic structure, and lifecycle research may prove most promising towards advancing our current systemic knowledge.

However, despite all our research efforts, we have no coordinated salmon and steelhead plan for the broader community of salmonid researchers working in the Central Valley and the San Francisco Estuary. To make better progress towards CALFED goals for increasing natural salmonid populations, we need an overall plan to improve, augment and integrate system-wide monitoring and research. This will first require determining which areas of monitoring and research (e.g. processes affecting juvenile survival, physical conditions, oceanic influences, genetics) are priorities for managers, and then committing funds and resources towards these priorities.



## MANAGEMENT IMPLICATIONS

### *Mitigation*

- Wild steelhead abundance on the Feather River might be enhanced by improving gravel conditions within the Low Flow Channel, creating additional channel complexity within the Low Flow Channel, and providing colder waters downstream of Thermalito Outlet (Cavallo).
- When managed for flow and temperature, Clear Creek appears suitable to all life stages of spring Chinook, but potential exists for hybridization of spring and fall Chinook. Barriers could help in management of ESUs as separate populations (M. Brown).
- Hydrodynamic studies suggest that 'hot spots' that provide habitat for large numbers of adult Chinook salmon seem to exist in the Delta. These could provide targets for management and research, and include the Rio Vista Bridge, above the Delta Cross Channel, and the Sacramento River tributaries near Cache Slough (Stein).
- Identifying how adult salmon react to certain flow scenarios in specific Delta channels could be crucial in designing a Through Delta Facility to facilitate salmon passage (Stein).
- The Delta is potentially important rearing habitat for Chinook salmon: restore the fish habitat and hopefully the fish will come (Brandes).

### *Hatcheries*

- The migratory behavior of wild and hatchery steelhead is different: hatchery steelhead may migrate

sooner than wild fish. Managers could coordinate hatchery releases and water management practices, especially SWP/CVP exports, to maximize emigration survival (Foss).

- Hatchery steelhead act differently from wild fish in timing of immigration, growth rates, and sex ratios, all of which could inform modeling and management of populations (Titus).
- Continued ozone treatment of hatcheries against IHNV could help avoid infecting wild populations (Foott).
- Salmonid hatcheries need to be viewed together as a system, rather than managed individually. FRH practices need to be modified, along with continued research and monitoring, with better coordination among Central Valley salmonid hatchery staff and fisheries managers (R. Brown).

### *Monitoring, Modeling and Indices*

- Because wild juvenile steelhead can contribute very little to adult spawning populations, monitoring adult steelhead abundance has more relevance for management of this species. This monitoring will be most useful if it distinguishes between hatchery and wild origin steelhead (Cavallo).
- The Delta and Fisher length at date models are commonly used to distinguish among Chinook salmon races but do not effectively differentiate spring-run juveniles. This could affect abundance and take estimates. Other methods such as genetic analysis may be more accurate for these purposes (McReynolds).

- A new multi-metric index encompasses greater resolution and more information than escape-management indexes. The index suggests management and restoration efforts may be inadequate to meet the accepted recovery goals for the San Joaquin Chinook salmon (Swanson).

### *General*

- Consideration of salmonid genetic diversity and its distribution across the landscape could allow for more effective conservation and restoration efforts. This could include management for distinct ESUs and locally adapted populations (Lindley, Nielsen, Blankenship).
- Hydrologic conditions occurring within the San Joaquin River watershed between 2000 and 2004 have limited VAMP experimental flow conditions to a relatively narrow range. Further tests, using the combination of higher San Joaquin River flow rates and two different levels of export rates, are needed to evaluate the respective roles of San Joaquin River flow and SWP/CVP exports on juvenile Chinook salmon smolt survival (Hanson).
- Disparate chemical and physical aspects of the environment work in interactive, cumulative ways to influence susceptibility to disease in Chinook salmon. A more holistic, ecosystem approach to management may be necessary (Loge).

## SCIENTIFIC INFORMATION

### Chinook salmon

#### *Population structure and genetics*

- Historical geographic analysis suggests that the viability of current Chinook ESU (Evolutionarily Significant Units, or locally adapted populations) is probably low because of substantial loss of diversity and spatial structure. Little can be said of the current status of independent populations of steelhead because of lack of data, although considerable habitat loss suggests a severe problem (Lindley).
- Genetic data indicate that run timing is more important than geography for describing genetic structure in upper Sacramento River Chinook salmon. Spring-run populations from different watersheds are more closely related to each other than spring and fall populations from the same river (Blankenship).
- Genetic divergence in Chinook populations is small, indicating potentially recent population radiation and/or substantial recent gene flow (Blankenship).
- Recent data suggest there is a large phenotypic spring run Chinook salmon in the Feather River (R. Brown).
- Chinook salmon daily and seasonal activity levels are regulated by two

CLOCK genes, which act as a primary molecular gear of the endogenous circadian clock. These genes have been cloned for the first time (O'Malley).

#### *Models, monitoring and indices*

- A life cycle spreadsheet model driven by freshwater conditions accounted for observed trends of adult winter-run Chinook salmon populations. No coherent signal from ocean survival was detected. Survival was positively influenced by increased flow and turbidity, and negatively by Delta Cross Channel gate position and delta exports (Cramer).
- A conceptual model of the winter run included processes affecting hatching and emergence, smolting emigration, ocean survival, and spawning migrations. It appears to predict observed trends of winter-run Chinook. The decline in harvest, changes in operation of the Red Bluff Diversion Dam and temperature control had the greatest influence on reversing population declines. Little or no effect of the Delta Cross Channel gate operation was found (Kimmerer).
- A multi-metric index exhibited a cyclical pattern with a significant overall decline in Chinook salmon from 1957-2003. Over the 47-year period, spatial structure improved slightly, and diversity declined significantly most

probably as a result of increased hatchery operations over the same period (Swanson).

- Fish biologists currently use two existing models used to help distinguish among Central Valley spring, fall, late fall, and winter-run Chinook salmon runs with the distinction primarily based on fish length at a given date. These models do not effectively differentiate spring-run salmon from the other races (McReynolds).
- At Clear Creek, the length at date models mentioned above mis-assigned many juvenile spring Chinook to the fall run. Thus, spring Chinook juvenile production indices based on the downstream trap and using these models were likely inaccurate in most years. These indices could be improved by genetic run designation of existing and future tissue samples and continued operation of the barrier weir and second fish trap (M. Brown).
- The Juvenile Production Index (JPI) is derived from juvenile emigration data collected at rotary screw traps just below the Red Bluff Diversion Dam. Juvenile Production Estimate (JPE) estimates juvenile production through expanding carcass count data from winter Chinook spawning grounds. While the simpler JPI methodology may produce slightly more accurate estimates of fry production in the upper river, JPE produces comparable results and costs less (Gaines).
- New infrared scanning technology tested since 2002 on the Stanislaus River can distinguish striped bass and suckers from Chinook, but not Chinook from steelhead. Data suggest that fish were most active at dawn and around 4PM. 7% of fish had hook scars, and 25% were hatchery fish (Demko).

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## SCIENTIFIC INFORMATION CONTINUED

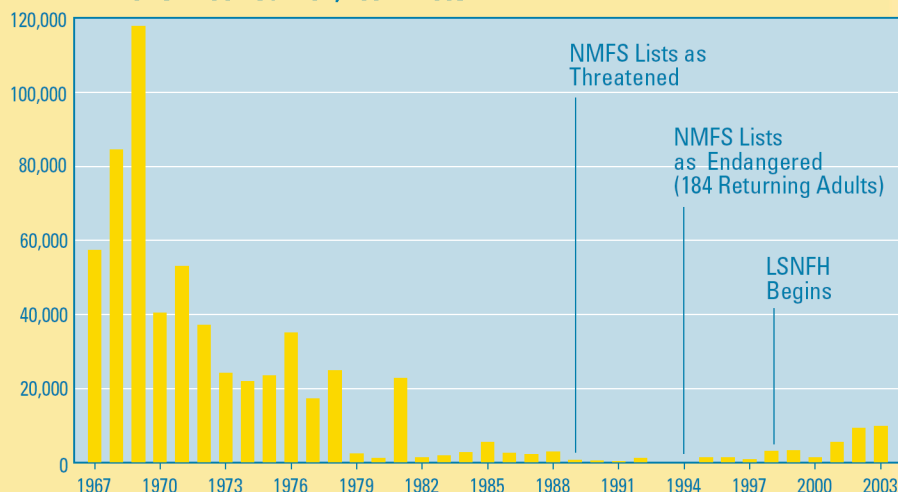
### Hatcheries

- Abundance of adult winter Chinook salmon increased as a result of the supplementation program at Livingston Stone National Fish Hatchery in all three survey years. Hatchery origin winter Chinook salmon returned to the same spawning areas as natural origin fish and spawned at approximately the same time as natural origin fish. Both male and female hatchery adults were generally smaller than natural origin fish (Null).
- Since 1967, Feather River Hatchery (FRH) has reared spring and fall Chinook salmon and steelhead to mitigate for habitat lost due to construction of the Oroville Dam complex. FRH practices and a barrier dam have resulted in hybridization between fall and spring Chinook runs (R. Brown).
- Hatchery fish stray to different rivers more than wild fish, particularly if hatchery fish are released off-site. Use of marked juvenile fall Chinook from the Feather River, Coleman and Merced hatcheries for studies in the Delta and elsewhere has also increased straying to non-natal streams and exacerbated the problem of homogenization of Central Valley fall Chinook runs (R. Brown).

### Migration

- Ultrasonically tagged salmon released from Montezuma Slough in fall 2003 mostly exited the Delta to the Sacramento River at Hood via the DCC. Most chose a northern Delta route instead of an interior Delta route (Stein).
- Conditions resulting from the Vernalis Adaptive Management Plan (VAMP) increased flows and decreased pumping appear to provide direct benefits to emigrating Chinook

## Population Estimates for Sacramento River Winter Chinook Salmon, 1967 – 2003



Population estimates for Sacramento River winter run Chinook Salmon, 1967 – 2003. Some points of historical interest are listed on the figure. 1979 was the culmination of a several-year drought. LSNFH – Livingston Stone Fish Hatchery (figure after R. Null, data from CDFG).

salmon smolts in the lower San Joaquin River. Survival improves as San Joaquin River flows increase and as the ratio between SWP/CVP exports and San Joaquin River flow decreases, but this relationship is not statistically significant. Indirect benefits of VAMP include improved water quality, fish monitoring, and hydrology monitoring (Hanson).

- A literature review suggests that rearing in the San Francisco Estuary, and particularly the Delta, is likely important to the production of Central Valley Chinook salmon. However, the relative importance of the Estuary varies by race and run, between the Delta and Bays, and between water year types (Brandes).

### General

- Hatchery epidemics and mortality of juvenile Chinook salmon due to infectious hematopoietic necrosis virus (IHNV) have occurred in the upper Sacramento River since 1941. In recent experiments, IHNV strains were less virulent for rainbow trout than for Chinook salmon. High virus doses induced infections and mortality among juvenile Chinook salmon, while low

doses, cohabitation or flow-through exposures did not. Under natural exposure conditions transmission of the virus to young wild salmonids is unlikely. The susceptibility of adult Chinook salmon to infection and the temporally overlapping runs may be the principal means by which IHNV is maintained in California watersheds. In spite of effective ozone treatment at hatcheries, returning fish still have the virus, probably because the disease maintains itself within large populations (Foott).

- In the Columbia River system, stress from dam turbines and chemical exposure influence susceptibility of fish to disease transmission. Hydro-power causes 5% delayed mortality, and chemical exposure resulted in 3-5% of delayed mortality (Loge).

### Steelhead

- Some local *O. mykiss* stocks, such as at Spring Creek, may be declining rapidly. Significant allelic differences were found in trout collected above and below impassable dams on the American, Yuba, Stanislaus and Tuolumne Rivers (Nielsen).

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## SCIENTIFIC INFORMATION CONTINUED

- Steelhead studies from 1999-2003 in the Feather River show that most steelhead spawning and early rearing occurs at the upstream end of the low flow channel (LFC) near the FRH. Rearing fish disperse over time to side channels. Rearing steelhead in the downstream portion of the LFC appeared to grow faster, and were generally larger than fish further upstream. Few steelhead seem to remain in the Feather River through their first year. Limiting factors other than flow and temperature conditions likely constrain steelhead populations in the Feather River (Cavallo).
- In 1998-2003 trawl and salvage studies, hatchery steelhead tended to emigrate sooner than their wild counterparts. Population estimates of wild juvenile steelhead ranged from 1.52 million in the 2001-2002 season to 2.18 million in the 1997-1998 season (Foss).
- Comparative field and laboratory studies in 1999-2002 show more wild females than males emigrated from the upper Sacramento system and moved seaward from the Delta. In contrast, hatchery steelhead smolts left the upper Sacramento system in nearly equal proportions of males and females, but left the Delta in a sex ratio similar to that of wild smolts (Titus).
- Juvenile steelhead growth rates can be as high as ~1 mm/day, and body size seems to be the primary determinant of smolting. Lower American fish typically reach smolt size within one year. Sacramento River fish smolt between 200-230 mm and can vary in age one to three to reach this size. Hatchery smolt emigration from the upper system peaked during late January-early February

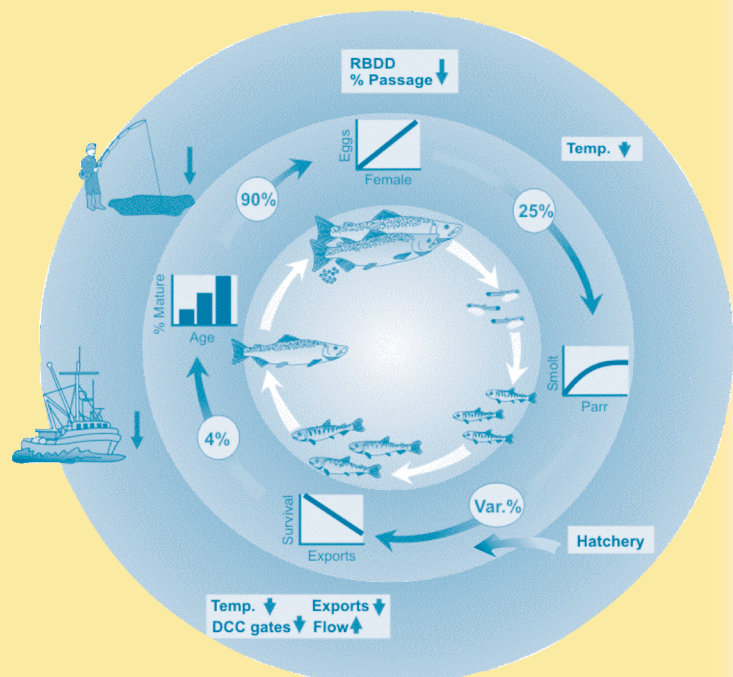


Rotary screw traps used for a Chinook salmon Juvenile Production Index below Red Bluff Diversion Dam.

while wild smolt emigration peaked during mid-April to mid-May (Titus).

- Otolith chemistry experiments suggest that life history form in *O. mykiss* is flexible and influenced by local conditions. Exchange rates between anadromous and non-anadromous forms influence the dynamics and extinction risk of steelhead populations (Donohoe).
- Studies have shown that FRH practices and an impassable fish barrier dam have changed steelhead run timing. Most of the fish now enter the hatchery in the winter, whereas before Oroville Dam most fish passed the dam site in the fall (R. Brown).
- Genetic analysis from 1999-2003 suggests significant regional structuring of populations exists among steelhead and trout populations throughout the Central Valley. Hatchery populations were shown to be similar in genetic diversity to geographically proximate wild populations (Nielsen).

### Chinook Life Cycle Model



Spreadsheet-based Chinook salmon life cycle model (figure courtesy S. Cramer).

# Native and Resident Fishes

Fred Feyrer (DWR) and  
Matt Nobriga (DWR)  
Session Chairs

## Background

We are painting on a contaminated canvas: native fish species are in the minority in most regions of the San Francisco Estuary. While the CALFED Record of Decision charges us to “restore habitats in the Delta, San Pablo Bay, Suisun Bay, Suisun Marsh, and Yolo Bypass including tidal wetlands and riparian habitat,” it does not specify exactly how we are to achieve these goals. Information presented in this session suggests we now know enough to predict the likely response of fishes to habitat restoration in the Delta on broad scales. However, maximizing the benefits to native species requires a detailed understanding of the environmental setting, ecological interactions, and pragmatic realities associated with aquatic habitat restoration.

The emphasis for management of fishes in the Estuary shifted to an ecosystem approach with the listing of delta smelt as threatened in 1993, and the Bay-Delta Accord and X2 standards in 1994-1995. Prior to these changes, the emphasis was on a small number of fish species, with monitoring and research directed primarily at striped bass. While salmon and steelhead remain priority species, recently much research has been done on a broad range of native species that use the Estuary. As we attempt to gain a holistic understanding of the ecology of the Estuary, three themes dominate the research findings presented here: location, life history, and the introduced aquatic weed *Egeria*.

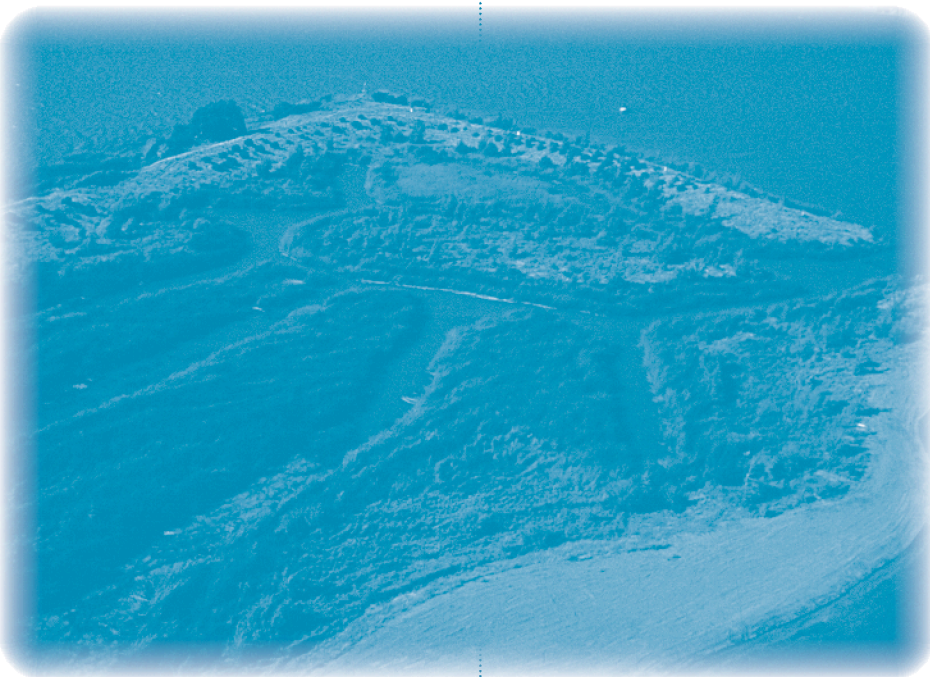
Location is of paramount importance: the North and West Delta, and points downstream, have greater restoration potential for native fishes than the eastern, central and southern regions of the Delta. However, project design and execution are important in restoration. Habitat features relevant to fish transcend categories like “shallow water habitat,” “channel edge” or “flooded island” (Nobriga). Habitat complexity and micro-habitat features known to benefit native fishes include seasonally and tidally inundated habitats, and turbid, open-water habitats.

The Delta was historically a vast tule marsh fed by rivers connected with their floodplains in most years. Thus, knowing the life history requirements of species of concern is essential to effectively linking restoration design with restoration goals. For instance, splittail benefit from high river flows because high flows provide large-scale floodplain inundation, which enhances splittail reproductive success. Juvenile Chinook salmon also may benefit

from periodically flooded areas, and tidally flooded areas; even very small floodplains can provide rearing benefits for Chinook salmon fry (see Floodplains, page 26).

*Egeria densa* is one of the main invasive Submergent Aquatic Vegetation (SAV) in the Delta. *Egeria* profoundly affects the upper estuary ecosystem because it provides ideal habitat for several nonnative species that are predators and/or competitors of native resident fishes. One of these species is largemouth bass, a voracious predator that frequents low-flow habitat within and adjacent to SAV. *Egeria densa* expanded greatly in range and density throughout the system between the 1980s and 2000s, particularly in the East, South, and West Delta (Brown).

“What habitat types should we build, and where?” is only the first part of the native fish restoration question. To achieve desired outcomes for species of concern, we need to improve our understanding of the linkages between habitat and species needs at various stages of their life cycles. Research in this session addresses this need.



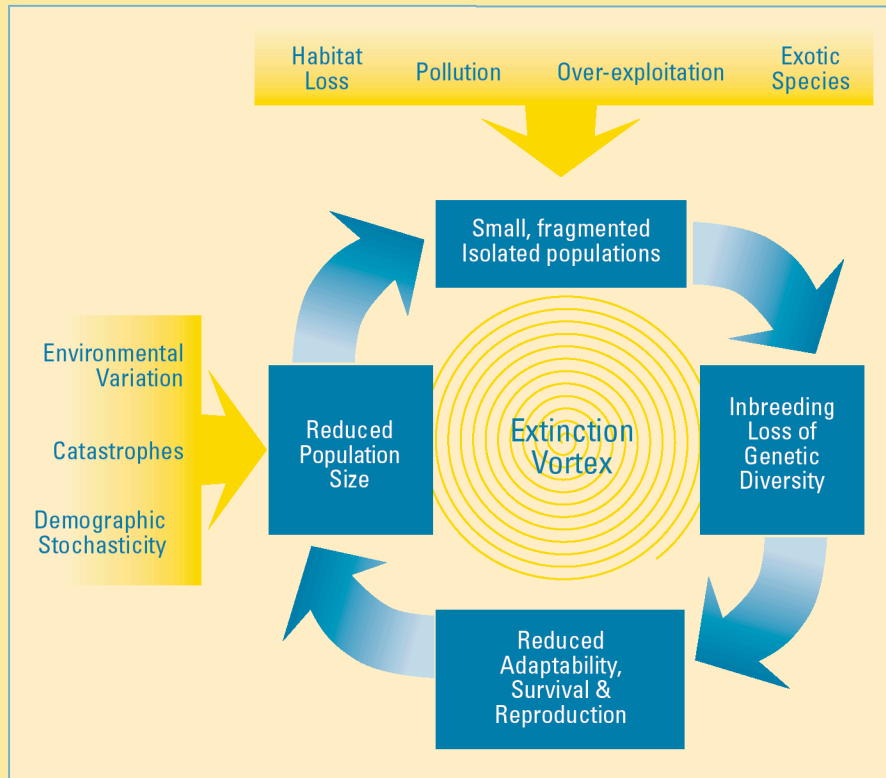
Decker Island restoration site, 2004.

## SCIENTIFIC INFORMATION

### Location

- Splittail (*Pogonichthys macrolepidotus*) adults return to brackish habitat in Suisun Marsh after spawning on floodplains and/or other suitable edge habitats (Feyrer). Young-of-the-year rear in riverine edge and backwater habitats, then migrate to the Estuary. Once in the estuary, splittail mostly inhabit smaller channels, backwaters, and sloughs. The splittail population correlates more strongly with floodplain inundation than with spring flow or X2. Limiting factors in the marsh for splittail include drought or water diversions (Schroeter).
- The upstream-most distribution of early life stage splittail in the Sacramento River has remained persistent over the past three decades. The distribution of juvenile splittail shifts upstream in years of low flow, as much of their suitable spawning habitat is upstream of rip-rapped areas of the Sacramento in dry years when lower river floodplains are not extensively inundated (Feyrer).
- The Petaluma and Napa rivers have splittail populations that are genetically different from populations in the Suisun Marsh and Sacramento-San Joaquin Delta. This may be evidence that splittail choose their spawning tributaries based on their natal origin (Baerwald).
- Analysis of DFG Tow Net Survey data suggests the decline in delta smelt (*Hypomesus transpacificus*) abundance has been greater in the central and south Delta than in Suisun Bay and the lower Sacramento River, which may reflect increased take at the pumps and/or greater habitat degradation in the central/

## Importance of Determining Population Structure



*Small, fragmented, isolated populations can lead to reduced populations through mechanisms shown in this conceptual model of an "extinction vortex." This concept highlights the need to protect different groups because they are evolving separately towards independent evolutionary paths (figure courtesy M. Baerwald, after Frankham R, Ballou JD, Briscoe DA (2002) Introduction to Conservation Genetics. Cambridge University Press, Cambridge, UK.)*

southern Delta. Delta smelt relative abundance may respond to spring export levels, which have been trending upwards despite EWA, VAMP and b(2) environmental flow releases (Fleming).

- Use of strontium isotopes in otoliths (ear bones) may be a useful tool to improve understanding of delta smelt rearing habitat. The Napa River, Suisun Marsh and the Delta contributed relatively evenly to the adult population sampled by the 1995-2002 DFG Fall Midwater Trawl. Growth rates during the larval stage varied, and were related to natal site. Smelt born in Suisun Marsh had earlier birthdates (earlier spawning) than those from the Napa and Sacramento rivers. Otolith data indicated that larger fish (born sooner) have greater survival and reproductive

potential. Thus, fish from productive habitats may contribute more to the overall population than monitoring numbers alone would suggest (Hobbs).

- In Suisun Marsh, tule perch (*Hysterocarpus traski*) are found in only two small sloughs, and may be effectively excluded from other areas of Suisun Marsh by low dissolved oxygen, habitat quality, and introduced species (Schroeter).
- Nonnative fish dominate the nearshore resident fish community. The number of native fish in the Sacramento and North Delta was independent of flow, but the number of Central Delta natives varied with Delta inflow (May).

## MANAGEMENT IMPLICATIONS

- Aquatic habitat restoration in the North and West Delta and downstream into Suisun will likely yield the greatest native species benefits, but must be done carefully as shown by Rockriver. We can improve habitat value in the South Delta, but it is likely these habitats will always be dominated by nonnative fish species because of the extensive hydrodynamic alterations.
- Brackish tidal marsh is habitat made up of fringe marshes and tidal channels and sloughs, with a mix of salt and freshwater and a dominance of tules and reeds. Many of these areas (such as Suisun Marsh) hold promise for restoration and native species conservation because of their productivity, the complexity of their habitats, and their importance in the life history stages of several important estuarine fishes. Several native fishes seem to do relatively well in brackish marsh habitat. In addition, downstream of the Delta there is no *Egeria*. There is high restoration potential here due to minimal encroachment and "lighter" land use practices (Schroeter).
- Releases of environmental water may not be sufficient to offset the environmental impacts of water diversion. Incidental take levels at the pumps would more accurately reflect population status if they were based on smelt abundance levels, rather than on historical salvage levels (Fleming).
- Petaluma River, Napa River, and Suisun/Delta populations of splittail could potentially benefit from being managed separately (Baerwald). Backwaters and offchannel areas could be managed as important rearing habitat for splittail (Feyrer). High reproductive potential means Suisun/Delta splittail will likely persist if adequate spawning habitat is preserved and their reproductive potential remains high (Culberson).
- Increased productivity in the Estuary will only help native fishes if this productivity is available in habitats native species use (No-briga).
- Land use in the marsh (such as duck pond discharge) can affect dissolved oxygen. Changing land use and may represent a management tool for fish species of concern (Schroeter).
- Current management emphasizes water exports as a driver of delta smelt mortality over food availability. A population model indicates that the actual order of importance may be the other way around. The potential benefits of CALFED's Environmental Water Account (EWA) for smelt may not be large enough to measure (Bennett).
- Population viability analysis results suggest delta smelt could qualify as an endangered, rather than threatened, species (Honey).
- Pesticides and their degradation products are being recycled through the food chain in biologically relevant levels, and maternally transferred to larvae in striped bass. These findings suggest sublethal effects of contaminants may be occurring in other fish species of concern in the Estuary (Ostrach).
- If restoration projects can minimize the occurrence of *Egeria* they will likely provide greater benefits to native fish species, but how to control and reduce *Egeria* is uncertain. Without reduction of *Egeria*, restoration of Delta shallow water habitat will not provide benefit to native resident fishes.

## SCIENTIFIC INFORMATION CONTINUED

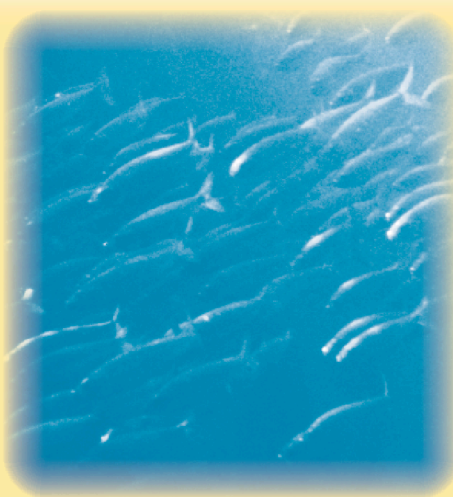
### Life History

- Splittail are broadly distributed throughout the San Francisco Estuary. Diet of young juveniles varies among habitats or regions – copepods are the dominant food sources in main channels, while chironomids are the dominant food in their preferred habitats - backwaters and floodplains (Feyrer).
- Statistical correlations between flow variables or X2 and splittail abundance as indexed by the DFG Fall Midwater Trawl survey is not merely an effect of flow on distribution. There is a link to production of juveniles upstream as well (Feyrer).
- Determining population genetic structures for species of concern is important because of the potential for an "extinction vortex" resulting from impacts to metapopulations caused by habitat loss, exotic species, or other impacts. The danger is that small, fragmented, isolated populations are vulnerable to inbreeding and loss of genetic diversity, which can reduce adaptability and survival, ultimately reducing population levels in a downward spiral towards extinction (Baerwald).

- continued

## SCIENTIFIC INFORMATION CONTINUED

- New modeling results suggest splittail population dynamics depend on the fecundity and longevity of the species, and that the species is likely to persist in the face of future environmental variability. Fish from different modeled populations grow at different rates, with different limiting factors. Reproductive potential is critical to population persistence (Culberson).
- Threats to reproductive potential such as pollution, pharmaceutical residues, or reduction of flood plain connections could pose new risks for splittail populations. Splittail will benefit from restoration actions that improve floodplain connectivity on a seasonal basis. Offchannel areas are the most important nurseries for splittail. These include bypasses, setback levees, seasonal depressions, levee breaks, and shallow fresh backwaters (Culberson).
- Interannual variation in river flows affects the proportion of the delta smelt population vulnerable to the State and federal water diversions. They may be “doomed by their biology” (Fleming). In drier years, young delta smelt are relatively abundant in the Delta, which makes them more susceptible to entrainment during spring (Fleming).
- For delta smelt, management has relied on the use of indices of abundance rather than estimates of actual abundance. These indices identify long-term trends, but do not allow estimation of the number of fish in the Estuary. New work translated indices to coarse abundance estimates. When combined with population models, abundance estimates present a step towards investigating the probability of delta smelt extinction, the role of human



activities, and potential restoration options for delta smelt (Bennett).

- Mortality at different life stages may have nonlinear effects on the delta smelt population. New modeling shows that poor feeding success was a more important mechanism for delta smelt mortality than exposure to toxic substances or exports in 1999-2001. Exports may impact delta smelt populations, but these impacts may be difficult to measure (Bennett).
- Population Viability Analysis can quantify the probability that a population will fall below a pre-defined extinction level. This technique was used to model population change, project future status, and frame uncertainty surrounding delta smelt population levels. These methods, which incorporate abundance estimates based on trawl indices, project a 50% chance of delta smelt crossing an ‘extinction threshold’ of 8000 fish within 20 years (Honey).
- 1+ year old delta smelt occur in the wild (and thus possibly spawn). A stage-based population model suggests 1+ year old fish may significantly buffer the population from years of poor spawning success (Honey).
- Striped bass were used as a model organism to investigate maternal

transfer of PCBs, PBDEs, and pesticides to larvae. The authors found higher levels of these compounds in the larvae of wild-caught females than in hatchery-raised fish. They also demonstrated adverse effects on growth and development, damage to reproductive and nervous system and liver abnormalities, and effects consistent with endocrine disruption (Ostrach). (See also Contaminants, page 66).

### *Egeria*

- The nearshore resident fish community has been functionally changed by *Egeria*: nonnative species became more abundant and native species less abundant in nearshore habitats between the 1980s and 2000s. Nonnative resident fishes are most common where *Egeria* is most abundant and the nonnative catch is dominated by centrarchids (black basses and sunfishes). Changes in water inflow or water clarity were not correlated with increases in nonnative species (Brown).
- Expansion of *Egeria densa* has provided additional rearing habitat for juvenile largemouth bass, and may account for the relative success of this species compared to striped bass (Nobriga).
- Introduced fishes are using the Decker Island restoration project site more than native fishes, and introduced species are present in greater proportions than they are in a reference reach. Natives declined in the restored channels in the first months after restoration, and were nearly absent in the second year of sampling restored channels. These changes are related to increases in SAV at the site (Rockriver).